AD ____________________

USAARL REPORT NO. 73-5

DETERMINING THE SURFACE AREAS OF MINIATURE SWINE AND DOMESTIC SWINE BY GEOMETRIC DESIGN--A COMPARATIVE STUDY

BY

LCDR Thomas L. Wachtel, M.D.
CPT G. R. McCahan, Jr., DVM
SP5 William I. Watson, B.S.
Mr. Michael Gorman, B.S.

October 1972

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama 36360

NOTICE

Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia. Orders will be expedited if placed through the librarian or other person designated to request documents from DDC (formerly ASTIA).

Change of Address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

This document has been approved for public release and sale; its distribution is unlimited.

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The products referred to in this report are not considered as an endorsement by the authors or the Department of the Army.

AD ____________________

USAARL REPORT NO. 73-5

DETERMINING THE SURFACE AREAS OF MINIATURE SWINE AND DOMESTIC SWINE BY GEOMETRIC DESIGN--A COMPARATIVE STUDY

BY

LCDR Thomas L. Wachtel, M.D.
CPT G. R. McCahan, Jr., DVM
SP5 William I. Watson, B.S.
Mr. Michael Gorman, B.S.

October 1972

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama 36360

U. S. Army Medical Research and Development Command

The Vivarium of the United States Army Aeromedical Research Laboratory is fully accredited by the American Association for Accreditation of Laboratory Animal Care.

In conducting this research, the investigators adhered to the Guide for Laboratory Animals Facilities and Care prepared by the committee on the Guide for Laboratory Animals Facilities and Care, National Academy of Sciences, National Research Council. Humane procedures were utilized throughout, and a graduate veterinarian was in constant attendance to perform all surgical procedures and to ensure that all animals were fully anesthetized and insensitive to pain.

ACKNOWLEDGMENTS

The authors are indebted to Janice Speigner, Diana Patrick, John J. Barbaccia, C. D. Williams, James Hearn, Melvin Stewart, Cletus Faulk, Darolyn Perez-Poveda, Danny Carpenter, David Bellemore, Tom Downs, Richard Chapman, and Malcolm Kirk for their generous assistance, without which this project could not have been completed.

ABSTRACT

The geometric design method provides an accurate means of deriving the total body surface area (TBSA) of miniature swine and also the percentage of the TBSA for a given area. The formulae for TBSA derived for domestic swine and the "Rules of 5" are not applicable to miniature swine. The equation $S = 0.121\ W^{.575}$ provides a more accurate, quick assessment of TBSA of miniature swine.

APPROVED: ROBERT W. BAILEY
Colonel, MSC
Commanding

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

DETERMINING THE SURFACE AREAS OF MINIATURE SWINE AND DOMESTIC SWINE BY GEOMETRIC DESIGN--A COMPARATIVE STUDY

INTRODUCTION

Total body surface area is an essential requirement in assessing cardiac index,[1] calculating basal metabolic rate and heat exchange phenomena,[2-6] and determining the percentage of surface area burned[7-8] in man and laboratory animals. Formulae have been established for calculating total body surface area in swine,[7,9] and a method has been used for determining various portions of the pig's skin surface.[7] No data are available from which we might establish the applicability of these formulae and methods for miniature swine.

METHODS AND MATERIALS

Animals

White Minipigs* and white domestic crossbred pigs (See Table 1) were procured, quarantined, freed of internal and external parasites, and verified to be healthy prior to use in this study.

TABLE 1. Age, Sex, and Average Weight of Animals

Animal	Age (mos)	No. Male	($\overline{Kg}$)	No. Female	($\overline{Kg}$)
Minipigs	5-6	11	(23.8)	12	(21.7)
	20-22	5	(56.6)	14	(59.2)
	23-24	3	(60.4)	4	(70.3)
Domestic White	2-3	10	(31.2)	15	(30.8)
	3-4	7	(40.2)	4	(42.7)

The animals were fasted overnight, premedicated with atropine (1-2 mg) and Innovar-Vet** (1 cc/20 lbs), entubated, and anesthetized with Halothane

---

*Modified Pitman Moore Strain of Miniature Swine, Vita Vet Laboratories, Marion, IN 30952

**McNeil Laboratories, Ft. Washington, PA 19304

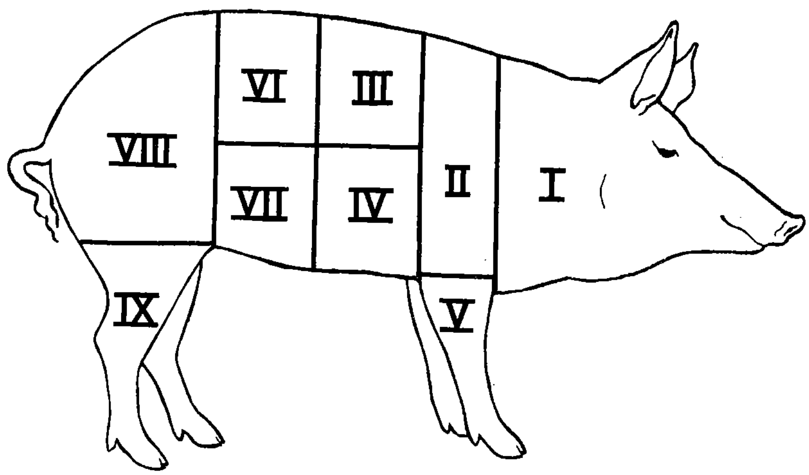
U.S.P.[10] The hair was closely clipped with a #40 clipper head prior to measurements and weights.

Measurements

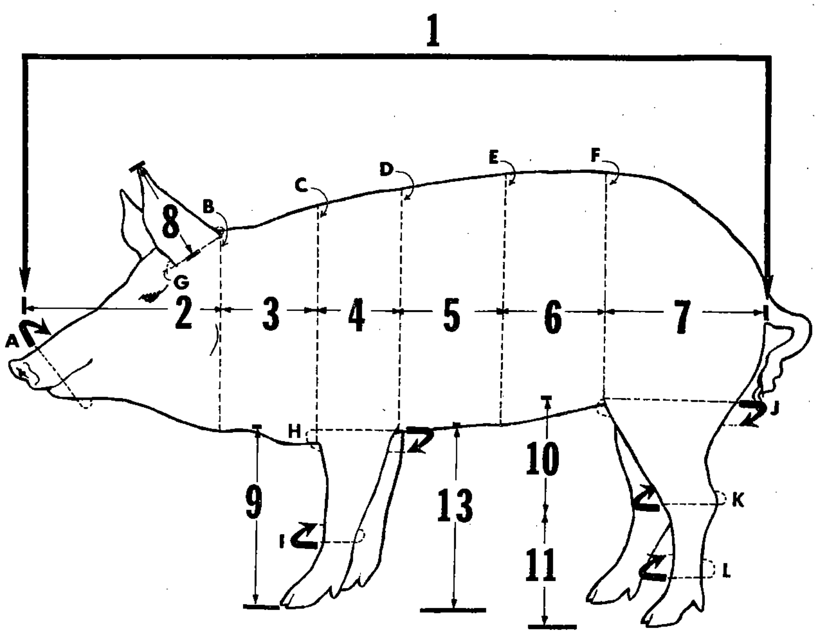
All measurements were made with the animal anesthetized and lying on its right side. A flexible steel tape graduated in one-sixteenth inch increments was used to obtain the circumferential and linear determinations indicated in Figure 1. Care was taken to define the measurement to the nearest quarter inch. Circumferential measurements were always made at end expiration. The tape was drawn snug without compressing the tissue.

FIGURE 1 (description*). Areas described are (unilateral): I. Head, Neck and Ears; II. Shoulder (excluding thoracic limb - Area V); III. Upper Forward Trunk; IV. Lower Forward Trunk; V. Thoracic Limb (entire); VI. Upper Rear Trunk; VII. Lower Rear Trunk; VIII. Hind Quarter (excluding pelvic limb - Area IX); and IX. Pelvic Limb (entire). Circumference of: A. Snout (immediately caudal of rostrum); B. Neck (immediately caudal of ears and angle of mandible); C. Shoulder (immediately cephalad of thoracic limbs); D. Heart Girth (immediately caudal of thoracic limbs); E. Mid-Trunk (equidistant from D and F); F. Rear Trunk (immediately cephalad of pelvic limbs); G. Ear (at base); H. Upper Thoracic Limb (directly around the leg as dorsal as possible); I. Lower Thoracic Limb (smallest distance); J. Upper Pelvic Limb (directly around the thigh as dorsal as possible); K. Mid-Pelvic Limb (at joint); and L. Lower Pelvic Limb (smallest distance). Lengths determined were: 1. Total length; 2. Head (tip of snout to B); 3. Neck (B to C); 4. Shoulder (C to D); 5. Forward Trunk (D to E); 6. Rear Trunk (E to F); 7. Hind Quarter (F to most caudal part excluding tail and genital organs); 8. Ear (tip of ear to G with ear at 90° to body); 9. Thoracic Limb (bottom of hoof to H); 10. Upper Pelvic Limb (J to K); 11. Lower Pelvic Limb (K to bottom of hoof); 12. Shoulder Height (bottom of hoof to top of shoulder - Not illustrated); and 13. Barrel Height (bottom of hoof to barrel).

*Terms from References 11 and 12.



UNILATERAL AREAS



LINEAR AND CIRCUMFERENTIAL MEASUREMENTS

FIGURE 1. Body Areas and Circumferential and Linear Measurements

Each animal was measured at least once by the senior author using precisely the method elaborated in the description and drawing of Figure 1. Repetitive measurements were made on some of the animals by the same investigator. Several animals were measured by other investigators using this method. Measurements were performed ante cibum and post cibum on four (4) animals.

Following each complete set of measurements the animal was carefully weighed on a 150 Kg anthropometric scale* (accuracy ±0.009 Kg).

Analysis

Total surface area was determined using the following formulae:[7,9]

$$S.A. = 0.1\ W^{0.62}$$

and

$$A. = 0.097\ W^{0.633}$$

Where S.A. or A. = surface area in square meters and W = weight in kilograms. A total surface area and fractional portions were determined using the following GEOMETRICAL DESIGN:

The numbered areas (Roman numerals) of the animal's body (See Figure 1) were represented by geometric figures. The head, neck, shoulders, abdomen, and legs were each described as frustrums; the ears as cones; and the hind quarter as a spherical segment of one base. Table 2 lists the equations for the area of each geometrical figure and Table 3 lists each area of the animal and the specific equations used with reference to the measurements shown in Figure 1. It should be noted that the lengths (Arabic numbers) in Figure 1 represent the length of a conical section measured along its surface, and the circumferences (letters) are used to determine the radii needed for the equations. All equations shown in Table 3 are in a reduced form and are derived from those equations in Table 2.

All data were reduced on a Hewlett-Packard (HP) Model 9100A Calculator** and plotted. The HP calculator was programmed to receive the geometric measurements and swine weight, perform the calculations shown in Table 3, and output the surface area of each portion of the animal, (i.e., S_1, S_2, etc.), total surface area, and the percent surface area of each

---

*Model 41-3314, Fairbanks Morse, Weighing Systems Div, Fair Lawn, NJ 07401
**Hewlett Packard Co., 1501 Page Mill Road, Palo Alto, CA 94304

TABLE 2. Basic Equations Used to Determine Body Surface Area of Swine

Figure	Equation	Definition
Spherical Segment of One Base	$A = 2\pi Rh$	A = Area R = Radius of sphere h = Height of spherical segment
Cone (Frustrum)	$A = \pi S\ (r + R)$	A = Area S = Length of cone measured along surface r = Radius of small end R = Radius of large end
Cone (Right Circular)	$A = \pi RS$	A = Area R = Radius of base S = Length of cone measured along surface
Circle	$R = C/2\pi$	R = Radius C = Circumference

TABLE 3. Equations Used in the Geometrical Model for Swine Body Surface Area

Area (See Figure 1)	Description	Geometric Figure	Equations*
I	Head	Frustrum	$S_1 = \frac{L_2(A+B)}{2}$
	Neck	Frustrum	$S_2 = \frac{L_3(B+C)}{2}$
	Ears	Four Cones	$S_3 = 2(G)(L_8)$
II	Shoulder	Frustrum	$S_4 = \frac{L_4(C+D)}{2}$
III & IV	Forward Abdomen	Frustrum	$S_5 = \frac{L_5(D+E)}{2}$
V	Fore Limbs	Frustrum	$S_6 = \frac{L_9(I+H)}{2}$
VI & VII	Rear Abdomen	Frustrum	$S_7 = L_6(F+E)$
VIII	Hind Quarter	Spherical Segment of One Base	$S_8 = (F)(L_7)$
IX	Rear Limbs	Frustrum	$S_9 = L_{10}(K+J)$ $S_{10} = L_{11}(K+L)$
	Point of Attachment of Limbs	Circle	$S_{11} = (J^2)(2\pi)$ $S_{12} = (H^2)(2\pi)$

$$\text{TOTAL SURFACE AREA} = \sum_{i=1}^{10} S_i$$

*Lengths (L_2, L_3, L_4, etc) and circumferences (letters) shown in Figure 1

surface portion. The reduced data were then plotted vs. weight (Figures 2 and 3). A least squares fit of total body surface area and weight data was computed for a power curve of the form: $Y = aX^b$ [13,14]

where Y = Total body surface area
X = Weight in kilograms
a and b = constants

RESULTS

There were no untoward or unusual reactions among the animals from the anesthesia or procedures.

The total body surface areas for the Minipigs and domestic swine are shown in Table 4. The total body surface area derived by each of the three methods is plotted versus weight in Figure 2.

The percent that various portions of the pig's skin surface are of the total area is presented in Table 5. Figure 3 shows a correlation of these areas with increasing weight.

We were able to show an average 1.19 Kg (or 3.1% increase) change in body weight post cibum. The effect of this change on total body surface area is tabulated in Table 6.

The results of independent measuring are shown in Table 7.

The computed formula which is applicable to miniature swine is

$$S = 0.121\ W^{.575}$$

where S = total body surface area, and W = weight of the miniature swine in kilograms. A comparison of the total body surface area derived with this formula and that obtained from the geometrical design always was within 12%. Seventy-five percent (75%) of these comparisons were within 5%.

TABLE 4. Total Body Surface Area Determinations for the Same Animal Groups Using Various Methods

Animal	Age (mos)	Geometric Design	Brody Formula	Kingsley Formula
Minipigs	5-6	0.72 m^2	0.70 m^2	0.69 m^2
	20-22	1.27 m^2	1.27 m^2	1.24 m^2
	23-24	1.31 m^2	1.37 m^2	1.34 m^2
Domestic White	3-4	0.91 m^2	0.85 m^2	0.84 m^2
	4-5	1.05 m^2	0.99 m^2	0.98 m^2

TABLE 5. Comparison of Average Area Size and Percent of Total Body Surface Area (BSA) Using Geometric Design Determinations and Calculating Similar Average Area Size from Kingsley's Formula and Rules of "5"[6]

	Geometric Design										Kingsley's Rules of "5"									
	Minipigs						Domestic				Minipigs						Domestic			
	5-6 mos		20-22 mos		23-24 mos		2-3 mos		3-4 mos		5-6 mos		20-22 mos		23-24 mos		2-3 mos		3-4 mos	
Area	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)	m^2	(%)
I. Head, Ears, Neck	.075	(10.8)	.13	(10.8)	.14	(10.6)	.10	(10.7)	.11	(10.9)	.07	(10)	.12	(10)	.13	(10)	.08	(10)	.10	(10)
II. Shoulder	.03	(4.3)	.06	(4.9)	.07	(5.1)	.04	(4.0)	.04	(3.9)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
III. Upper Forward Trunk	.025	(3.4)	.04	(3.4)	.04	(3.5)	.038	(3.2)	.037	(3.5)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
IV. Lower Forward Trunk	.025	(3.4)	.04	(3.4)	.04	(3.5)	.038	(3.2)	.037	(3.5)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
V. Thoracic Limb	.05	(6.8)	.07	(6.0)	.07	(5.5)	.06	(6.6)	.06	(6.0)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
VI. Upper Rear Trunk	.023	(3.3)	.04	(3.3)	.04	(3.5)	.033	(3.4)	.037	(3.5)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
VII. Lower Rear Trunk	.023	(3.3)	.04	(3.3)	.04	(3.5)	.033	(3.4)	.037	(3.5)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
VIII. Hind Quarter	.045	(6.5)	.10	(8.2)	.11	(8.8)	.06	(6.5)	.07	(6.8)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
IX. Pelvic Limb	.06	(8.2)	.08	(6.4)	.075	(5.8)	.08	(8.7)	.08	(8.0)	.03	(5)	.06	(5)	.07	(5)	.04	(5)	.05	(5)
TOTAL BSA	.72	(100)	1.27	(100)	1.31	(100)	.91	(100)	1.05	(100)	.69	(100)	1.24	(100)	1.34	(100)	.84	(100)	.98	(100)

TABLE 6. The Net Change in Body Surface Area Post Cibum (ante cibum measurements made after total overnight fast)

Method	Δ Weight (Kg)		Δ Total Body Surface	Δ Percent
Geometric Design	1.19 Kg	3.1%	0.025 m^2	0.06
Brody's Formula	1.19 Kg	3.1%	0.025 m^2	0.05
Kingsley's Formula	1.19 Kg	3.1%	0.01 m^2	0.03

TABLE 7. Average Surface Area and Regional Area Percentage for an Investigator Making Independent Determinations ($A + A^1$) and for an Independent Investigator Making Measurements (B) on the Same Four Domestic Swine

	% Total Body Surface Area*		
Area	A	A^1	B
I	11.1	10.8	10.9
II	6.1	6.4	6.0
III	3.4	3.4	3.4
IV	3.4	3.4	3.4
V	4.2	4.2	4.6
VI	3.5	3.7	3.8
VII	3.5	3.7	3.8
VIII	6.1	6.2	6.0
IX	8.0	8.1	8.0
TBSA*	0.97	0.98	0.97

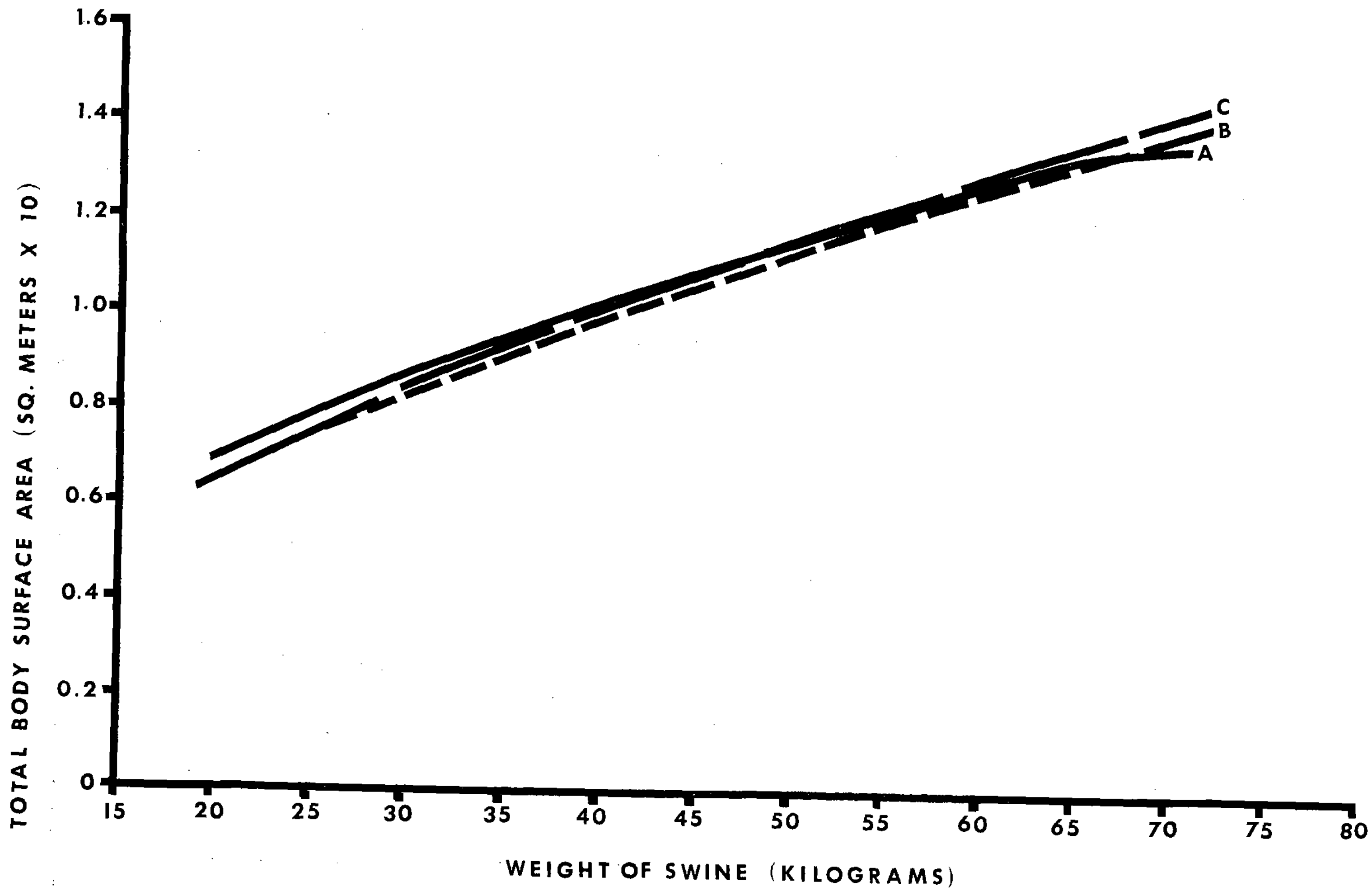
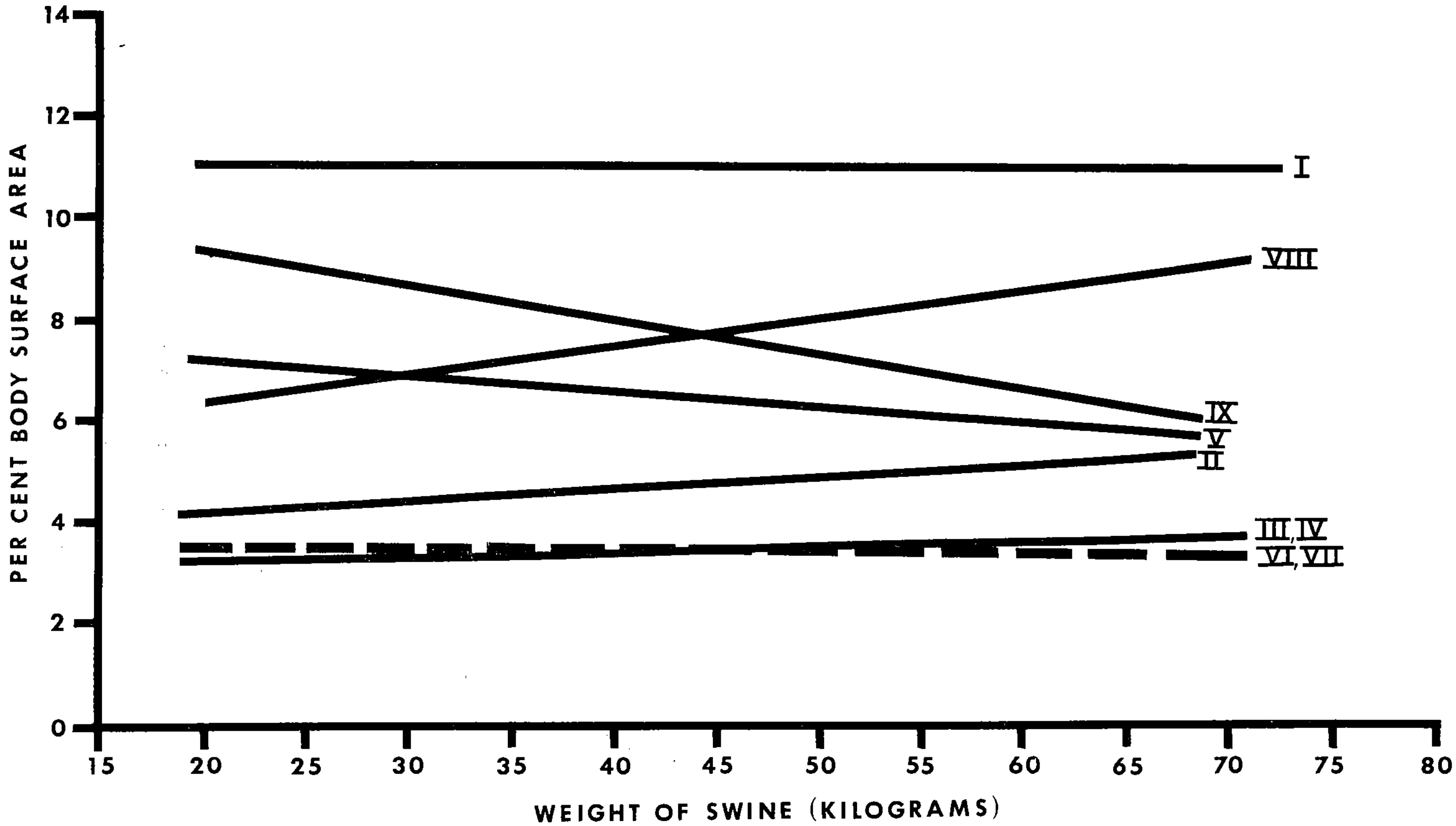


FIGURE 2. Linear Plot of the Total Body Surface Area Determined by Geometric Design (A), Kingsley's Formula (B), and Brody's Formula (C) Versus Weight of Domestic and Miniature Swine



I. Head, Neck & Ears; II. Shoulder (excluding thoracic limb - Area V); III. Upper Forward Trunk; IV. Lower Forward Trunk; V. Thoracic Limb (entire); VI. Upper Rear Trunk; VII. Lower Rear Trunk; VIII. Hind Quarter (excluding pelvic limb - Area IX); & IX. Pelvic Limb (entire).

FIGURE 3. Linear Plot Correlating the Various Areas of the Pig with Increasing Weight

DISCUSSION

Calculated surface areas are the rule in all physiological work at the present day.[3,6] This is certainly true in human medicine where it is still customary to express metabolic rate as the number of calories produced per square meter of body surface per hour.[2] The square meter of body surface is also an important unit of measure in prediction of metabolic rate.[5] However, this does not mean that the "surface area law" is without limitations, for despite the historical background of surface area being the unifying biological principle in expressing metabolic rate, Benedict has found no such concept among warm blooded animals.[6]

Aside from surface area as it relates to metabolic rate is the necessity of knowing the total body surface area of a miniature swine and representative parts thereof if such an animal is to be used in physiologic experiments (e.g., burn shock model).

However, determining surface area in animals is a difficult task[14] as evidenced by the many methods that have been devised for measuring the surface area of animals.[15] These include the principle of triangulating the surface of the body and measuring these several triangles individually,[6] skinning with planimetering,[4,6] surface integrator,[9,14] moulding,[4,6] photographic,[14] and others.[4,14] To further complicate matters, physiologic data often are expressed in reference to surface area without sufficient data to provide an insight as to how the surface area was determined.[5]

In 1879 Meeh marked out in geometric designs the bodies of six adults and ten children. From these measurements he derived the formula $S = KW^{2/3}$ in which K is a constant for a given species[3] or for a group of similarly shaped animals but differs according to the shape of the animal.[5] Rubner used this formula in his calculation of the surface areas of animals.[3]

A critical analysis of the formula shows several sources of error. The most variable factor in the formula has been the so-called constant K.[3,6] This stems from the difficulties in deriving K by measuring the surface areas of animals of even simple geometric design, such as the snake. The actual measurement of the area of the skin after skinning always gives a greater value than the calculated one, in spite of all precautions to avoid stretching[6] (an almost inevitable occurrence with skinning). Mitchell has shown in the case of the rat that the surface area depends on the position of the animal[3] and that when skinned and measured with a planimeter or by cutting out a corresponding figure of paper whose weight divided by the weight of a square decimeter of the same paper, his method expresses the surface area in rather vague results compared to the mould method.[4] Brody further states that the surface area of a living

animal is not constant and cannot be measured in such a manner that the results can be checked by different investigators.[14] The pig is, of course, susceptible to each of these variables.

Because of the vagueness of the definition of animal surface area[4] and the fact that surface area is difficult or impossible to measure accurately, metabolic rate is usually not expressed as a function of surface area in animals,[2] but as a function of the metabolic weight, a power function of body weight.[2,4,6] This method is not without a major source of inaccuracy which is common to all formulae using a reference weight.[4] Gut contents in cattle can account for 22-23% of the total body weight and can change very much indeed,[4] and the intestinal contents of the rabbit can be 13% of the body weight.[3] We explored this variable in our swine and despite a 3.1% change in body weight, we were not able to show any significant change in the body surface area by our method (or by Brody's or Kingsley's formulae) following specific comparative studies on ante cibum vs. post cibum total body surface areas. However, the recommended twelve-hour overnight fasting[3,6,16] or a calculated intake would logically provide a better reference weight.

A major question has been raised as to whether the empirical exponents of weight (i.e., $W^{3/4}$) might be difficult to apply to the miniature pig or to pigs with the present-day growth rate in metabolic studies.[4] An equally cogent question is whether the configuration of our present miniature pigs is in any way comparable to the swine upon which the previous formulae for surface areas have been derived.

In Kingsley's formula for swine, appropriate marks were made on the skin of the animals, distances measured, the animals then skinned, the skins laid on paper and with a planimeter, areas determined. It was from this that he came up with the "Rules of 5" for pigs,[16] where each number indicates the percent that particular area is of the total[7] (See Figure 1 and Table 5) and is an adaptation to the pig of the "Rules of 9" for humans.[8] He used the animals that died in other projects for his study;[16] however, Brody called attention to the fact that not even surface measurements on dead animals had led to reproducible results.[14]

Brody established a formula also for determining the total body surface of swine.[9] This formula is not too unlike that of Kingsley's and is based on a modification of the "surface law" and the metabolically effective body size (i.e., $W^{2/3}$).[14]

We developed the geometric design for determining the total body surface area of miniature swine because of the uncertainty of existing data for domestic swine being applicable to this breed. The idea was

certainly not original, for Meeh,[3] Kingsley,[7,16] Benedict,[6] and others have utilized some form of the geometric approach to determine their constant K. Mount, however, warned that a geometrically determined surface cannot be universally valid in making comparisons between animals.[4] It was, nevertheless, equally important that we be able to determine the amount of skin in a given area so that we could calculate the percent of total body surface area.

We applied our method to groups of Minipigs and domestic swine. Comparative studies showed that the geometric design gave a consistently larger body surface area than the other two formulae in the domestic swine for which the formulae had been derived. In the miniature swine the same relationship occurred in the younger or smaller animals, although to a lesser degree. As the miniature swine matured the geometric design showed a smaller total body surface area than either of the other two formulae. From these data we could deduct that the formulae established for domestic swine are not directly applicable to miniature swine.

Because it was time consuming and subject to some variation to obtain all the measurements necessary to derive the body surface area by geometric design, we derived a formula using our data which represents the total surface area of miniature swine as a function of weight. We avoided introducing linear measurements into the formula following the recommendation of Brody.[14] This formula proved adequate for estimating average total body surface area; however, for accurate determinations of body surface area for an individual animal, the geometric design is recommended.

We likewise assessed the value of using the "Rules of 5" for pigs. Our data showed that there were significant decreases in the size of the limbs with age or total body weight. The shoulder increased slightly and the hind quarter significantly with age or total body weight. The head, ears, and neck and the trunk were not significantly different under these same circumstances. There was disparity with the "Rules of 5" in all areas. This was most significant in the hind quarter and least in the shoulder. Likewise, the disparity was more apparent in the younger, smaller pigs than in the mature animals. While this "rule" may prove handy for rough assessment of a burned area, it was not precise enough for accurate percentage determination in critical analyses in miniature swine, and one should use the method which more accurately represents a given physical area.

CONCLUSIONS

Existing formulae for total body surface area derived for domestic swine are not applicable to miniature swine.

The "Rules of 5" for pigs is not accurate enough to assess the percentage of the total body surface for a given area.

The Geometric Method provides an adequate means of deriving the total body surface area of miniature swine and also the percentage of the total body surface area for a given physical area of the pig.

The formula $S = 0.121\ W^{.575}$ gives a more accurate, quick assessment of total body surface area of miniature swine than pre-existing formulae.

REFERENCES

1. Guyton, A. C.: Textbook of Medical Physiology, Philadelphia, W. B. Saunders, 1971, p. 311.

2. Dale, H.: "Energy Metabolism." In Duke's Physiology of Domestic Animals, 8th Ed., Swenson, M. J., Ed., Ithaca, Cornell University Press, 1970, pp. 619-633.

3. Gemmill, C. L.: "Energy Metabolism." In Medical Physiology, 11th Ed., Bard, P., Ed., St. Louis, C. V. Mosby Co., 1961, pp. 480-482.

4. Kleiber, M.: "Metabolic Body Size." In Energy Metabolism, Blaxter, K. L., Ed., London, Academic Press, 1964, pp. 427-435.

5. Kleiber, M.: "Body Size and Metabolic Rate." Physiological Review, 1947, Vol. 27, pp. 511-541.

6. Benedict, F. G.: Vital Energetics--A Study in Comparative Basal Metabolism, Publication No. 503, Washington, D. C., Carnegie Institute of Washington, 1938, pp. 18-19, 27-28, 50-56, 147-148, & 172-179.

7. Lyon, J. L., Emery, A. S., Jr., Pearse, H. E., et. al.: "The Relationship of Thermally Induced Hemoglobinemia to Volume of Skin Burn." The University of Rochester - AEC Report UR-401, 1955.

8. Wallace, A. B.: "The Treatment of Burns." Practioner, Vol. 170, 1953, pp. 109-118.

9. Brody, S., Comfort, J. E. and Matthews, J. S.: "Growth and Development with Special Reference to Domestic Animals. XI. Further Investigations on Surface Area with Special Reference to its Significance in Energy Metabolism." Mo. Ag. Exp. Sta. Res. Bull., Vol. 115, 1928, pp. 3-59.

10. McCahan, G. R., Jr., and Wachtel, T. L.: "Anesthesia and Immobilization of Domestic and Miniature Swine--A Method and Some Problems." USAARL Report No. 73-7, US Army Aeromedical Research Laboratory, Fort Rucker, AL, December 1972.

11. Popesko, P.: Atlas of Topographical Anatomy of the Domestic Animals, Vols. I, II, III, Philadelphia, W. B. Saunders Co., 1971.

12. Tumbleson, M. E., Middleton, C. C., Tinsley, O. W., et. al.: "Body Weights and Measurements of Hormel Miniature Swine from Birth to Nine Months of Age." _Lab. Anim. Care_, Vol. 19, 1969, pp. 596-601.

13. Brownlee, K. A.: _Statistical Theory and Methodology in Science and Engineering_, New York, John Wiley & Sons, 1965, p. 36.

14. Brody, S.: _Bioenergetics and Growth_, New York, Hafner Publishing Co., 1945, pp. 352-403.

15. Benedict, F. G.: "The Surface-Area Constant in Comparative Physiology." _Yale Journal of Biol. & Med._, Vol. 4, 1932, pp. 385-398.

16. Kingsley, H. D., M.D., General Surgery, Highland Hospital, Rochester, New York: Personal communications, 1972.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U. S. Army Aeromedical Research Laboratory Fort Rucker, Alabama	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Determining the Surface Areas of Miniature Swine and Domestic Swine by Geometric Design--A Comparative Study

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Paper for publication

5. AUTHOR(S) *(First name, middle initial, last name)*

LCDR Thomas L. Wachtel, M.D.
CPT G. R. McCahan, Jr., DVM
SP5 William I. Watson, B.S.
Mr. Michael Gorman, B.S.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
October 1972	18	16

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 3AO 6211 OA 819 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 73-5 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY US Army Medical R&D Command Washington, D. C. 20314

13. ABSTRACT

The geometric design method provides an accurate means of deriving the total body surface area (TBSA) of miniature swine and also the percentage of the TBSA for a given area. The formulae for TBSA derived for domestic swine and the "Rules of 5" are not applicable to miniature swine. The equation $S = 0.121\ W^{.575}$ provides a more accurate, quick assessment of TBSA of miniature swine.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Surface Area						
Swine						
Miniature Swine						
Geometric						